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ENERGY $AVER$

"... For Business and Industry".

VOLUME TWO / NO. 2

SAVING MONEY THROUGH POWER FACTOR IMPROVEMENT

The Facts...

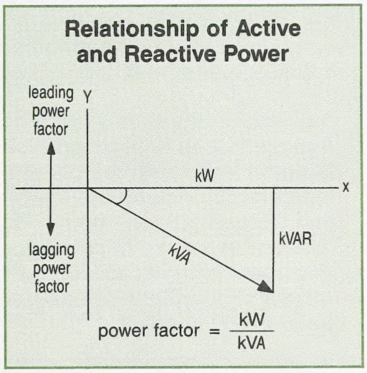
Many facilities in Alberta use more electricity than necessary due to a phenomenon known as poor power factor. Poor power factor can occur at facilities that operate equipment like inductive motors, transformers, welding machines and lighting ballasts. Electricity can be used more efficiently and at significantly lower cost if power factor is improved.

Power factor is the ratio of the power delivered by the utility company and the real power used to perform work. In the common inductive electrical motor, a certain amount of electricity is required to maintain internal magnetic fields but it produces no useful external work. This unseen component is called reactive power.

A low power factor indicates that a large portion of the total power received is reactive power which performs no usable work but does affect electrical costs. The power factor value can vary from low percentages to 100 per cent. A value close to 100 per cent is desirable because it means that nearly all the energy delivered is usable or active.

Three types of loads can be connected to an electrical system: resistive, inductive and capacitive. Resistive loads are devices like heaters, stoves and incandescent lights that use only active power.

Inductive loads are equipment such as motors, transformers and lighting ballasts which require both reactive and active power. For these types of equipment, the reactive power produces "lagging" power factor. The diagram below shows lagging power factor dropping below the horizontal axis.

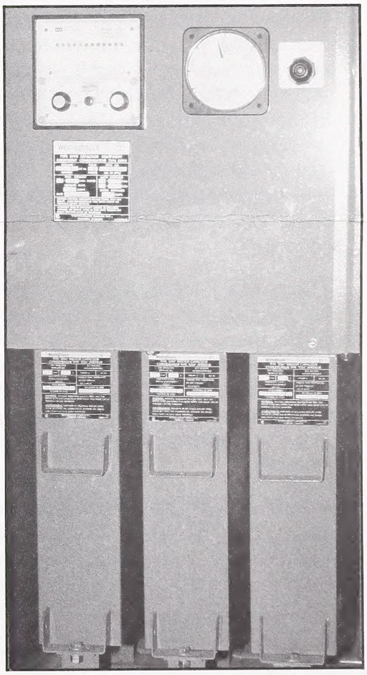


Relationship of Active and Reactive Power

Capacitive loads also require reactive and active power but the result is "leading" power factor, shown in the diagram as being above the horizontal axis. Capacitive loads are equipment such as capacitors, synchronous motors and synchronous condensers.

Poor power factor cuts down on the electrical system's capacity to carry kilowatts (i.e. wattage of the connected electrical motor or device, divided by 1000). The effect is that less active power can be supplied and, therefore, less work can be obtained from the system. In addition, a low power factor results in higher current (amperes) per kilowatt of active power which produces greater line losses (heat energy associated with the resistance of the line and the current flowing through it). Poor power factor can also result in reduced voltage, causing decreased power output for the entire system.

Power factor (or its effects) can be measured by different methods. The standard equipment used by electrical utilities in Alberta is a kilovolt-amperes (kV·A) demand meter designed to read kilovolt-amperes (kV·A) instead of kilowatts (kW). A spot check of the power factor occurring at any time can be calculated based on two readings from such meters – the current demand and the number of seconds it takes the meter disk to complete one revolution.



Main electrical room capacitor bank and controls

The formula used to calculate the power factor from these readings is:

$$\text{Power Factor} = \frac{\text{kH} \times 3600}{\text{internal meter multiplier} \times \text{current demand reading} \times \text{revolutions/sec. of the disk}} \times 100\%$$

Another way to measure power factor is to take simultaneous readings of volts, amperes, and watts and apply the following formula:

$$\text{Power Factor} = \frac{\text{watts} \times 1000}{\text{volts} \times \text{amperes} \times 1000} \times 100\% = \frac{\text{kW}}{\text{kV·A}} \times 100\%$$

If poor power factor is found, i.e. below 90 per cent, power factor correction should be investigated. Improving power factor to 90 per cent or greater could result in significant electrical cost savings.

The first step in power factor correction should always be a preventive one. Building owners and operators should ensure that all electric induction motors are sized to match the mechanical loads which the motor will be diriving. The closer the match of motor capacity to the applied load, the better the power factor. Excessively high voltage should be avoided as it can also result in poor power factor.

The most common method of power factor correction is the use of capacitors which receive and hold electrical charges. Capacitors which cause leading power factor can be installed at a particular load site, such as an induction motor, or on the main power supply to correct the lagging power factor associated with such loads. The rule of thumb is that capacitors should be placed as close to the inductive loads as possible.

The average cost of using conventional capacitors to correct poor power factor is about $50 per kVAR (kilovolt-amperes reactive) of capacitors installed. Using other power factor correction methods is likely to result in higher costs per kVAR of correction.

Prior to installation, building operators should investigate with their capacitor supplier whether resonance and harmonies (which may be present in the electrical system) are likely to be a problem. Also, it should be anticipated that, after capacitor installation, an increase in voltage is likely to occur.

Synchronous motors or synchronous condensors can also be used to improve lagging power factor. These devices are usually more expensive than capacitors and, therefore, are commonly used by large industrial plants.

The Application...

Palm Dairies is a major Alberta dairy product processor and distributor. In 1986, management requested an energy audit of their Calgary plant by staff of the Alberta Energy Bus program to assist in identifying how energy was being used and how they could improve efficiency and save on energy costs.

Spot testing of the power factor at the main electrical supply indicated a power factor of about 80 per cent. Based on this reading, Energy Bus staff determined that an annual saving of $19 800 in electrical costs would be possible if the power factor was improved from 80 to 95 per cent.

As a result of the audit, Palm Dairies arranged for an in-depth analysis of its power factor and the best method for correction. The analysis showed that occasionally the power factor dropped as low as 73 per cent and that a bank of eight capacitors, each rated at 75 kVAR, would correct it to close to 100 per cent.

Based on the analysis, Palm Dairies installed the eight capacitors, along with a number of controls and a switch gear for monitoring the power factor and for switching on the right number of capacitors to obtain the desired correction. The total cost of installation was about $45 000.

In 1989, Ken Mumby, Palm's plant superintendent, requested a re-audit to evaluate the effectiveness of the energy management measures they had implemented and to determine whether additional savings were possible. The power factor was rechecked and had improved to about 98 to 99 per cent.

Power factor correction savings were re-calculated based on the revised "before" and "after" power factor readings and the new electrical rate structure costs. New calculations showed that power factor correction was resulting in savings of $33 000 per year for Palm Dairies. This represented a 16-month payback period for the power factor correction equipment.

The Bottom Line...

Improving the power factor of an electrical system can result in significant electrical demand cost savings. Demand costs are based on the maximum amount of electrical energy used at any single time during the billing period. Before determining the potential savings from power factor correction, building owners and managers must first know the amount they are paying for demand.

Electrical utilities in Alberta use two basic rate structures. One structure has charges directly related to the demand (kV·A or kW) reading while the other has consumption (kW·h) blocks which are demand-related. Consumption is the total amount of power used by all electrical devices during the billing period.

Demand costs are determined by multiplying the cost of one kV·A of demand by the reading on the demand meter. Depending on the rate structure, costs will vary.

For a detailed explanation of electrical rate structures and how demand charges are determined by the electrical utilities, see *Electrical Rate Structure Knowledge Can Save Energy Dollars*, Vol. 1, No. 3, in this series of publications.

Once an applicable demand cost has been determined, an analysis of the potential for saving can be done. The example provided shows that improving power factor from 70 per cent to 90 per cent for an initial reading of 470 kV·A would result in a demand reduction of 104 kV·A.

EXAMPLE:

$$\text{Power Factor (70\%)} = \frac{\text{kW}}{\text{kV.A}}$$

$$\text{kW} = \text{kV.A} \times \text{power factor}$$

$$\text{kW} = 470 \times 0.70 = 329$$

At 90 per cent power factor, the new kV.A reading would be:

$$\text{Power Factor (90\%)} = \frac{\text{kW}}{\text{kV.A}}$$

$$\text{kV.A} = \text{kW/power factor}$$

$$\text{kV.A} = \frac{\text{kW}}{0.90} = \frac{329}{0.90} = 366$$

Change in kV.A demand = 470 − 366 = 104 kV.A.

On a demand-oriented rate structure (with a typical demand cost of $19.34/kV.A) the savings would be:

104 kV.A × $19.34/kV.A/month × 12 months = $24 136.32

On a consumption-oriented rate structure (with a typical demand cost of $5.75/kV.A), the savings would be:

104 kV.A × $5.75/k.V.A/month × 12 months = $7176.00

These calculations show how important it is to evaluate electrical costs based on the applicable rate structure and the amount of energy used. The potential for saving by reducing demand is much greater on a demand-oriented rate structure than on a consumption-oriented rate structure for the same power factor correction.

The next step is to determine the payback period for investing in power factor correction equipment. Using conventional capacitors to accomplish the correction, the average cost would be about $50 per kVAR of capacitors installed.

To determine the number of kVAR of capacitors needed to improve power factor from 70 per cent to 90 per cent, the following formula should be used:

kVAR of capacitors = kW multiplier × input kilowatts

The KW multiplier, in this case, is .536 (determined from Table 1). The input kilowatts is 329. The kVAR of capacitors required would be .536 × 329 = 176. Therefore, at $50 per kVAR, the capital cost would be $8800 (176 × $50). The payback period can be determined by dividing the capital cost of the equipment by the annual savings, multiplied by 12 months.

For the demand-oriented rate structure:
Payback = $8800/$24 136.32 × 12 = 4.4 months (or .36 year)

For the consumption-oriented rate structure:
Payback = $8800/$7176 × 12 = 14.7 months (or 1.23 years)

While there is a substantial difference in the payback periods based on the different rate structures, they are both economically attractive.

Contact your utility company for help in measuring your power factor or for specific measurements needed to calculate potential savings.

TABLE 1 kW Multiplier for kVAR Correction Determination

ORIGINAL POWER FACTOR IN PERCENT	DESIRED POWER FACTOR IN PERCENT										
	85	86	87	88	89	90	91	92	93	94	95
70	.400	.427	.453	.480	.508	.536	.564	.591	.625	.657	.691
71	.372	.399	.425	.452	.480	.508	.536	.563	.597	.629	.663
72	.343	.370	.396	.423	.451	.479	.507	.534	.568	.600	.634
73	.316	.343	.369	.396	.424	.452	.480	.507	.541	.573	.607
74	.289	.316	.342	.369	.397	.425	.453	.480	.514	.546	.580
75	.262	.289	.315	.342	.370	.398	.426	.453	.487	.519	.553
76	.235	.262	.288	.315	.343	.371	.399	.426	.460	.492	.526
77	.209	.236	.262	.289	.317	.345	.373	.400	.434	.466	.500
78	.183	.210	.236	.263	.291	.319	.347	.374	.408	.440	.474
79	.156	.183	.209	.236	.264	.292	.320	.347	.381	.413	.447
80	.130	.157	.183	.210	.238	.266	.294	.321	.355	.387	.421
81	.104	.131	.157	.184	.212	.240	.258	.295	.329	.387	.395
82	.078	.105	.131	.158	.186	.214	.242	.259	.303	.335	.389
83	.052	.079	.105	.132	.160	.188	.216	.243	.277	.309	.343
84	.026	.053	.079	.106	.134	.162	.190	.217	.251	.283	.317
85	.000	.027	.053	.080	.108	.136	.164	.191	.225	.257	.291
86	—	—	.026	.053	.081	.109	.137	.167	.198	.230	.265
87	—	—	—	.027	.055	.082	.111	.141	.172	.204	.238
88	—	—	—	—	.028	.056	.084	.114	.145	.177	.211
89	—	—	—	—	—	.028	.056	.086	.117	.149	.183
90	—	—	—	—	—	—	.028	.058	.089	.121	.155

SECTOR REVIEW

ENERGY USE IN THE FOOD AND BEVERAGE PROCESSING INDUSTRY

Energy use varies widely, depending on the type of building and the activities in that building. The extent of variation in energy use has become evident following Energy Bus audits of almost every type of facility in Alberta.

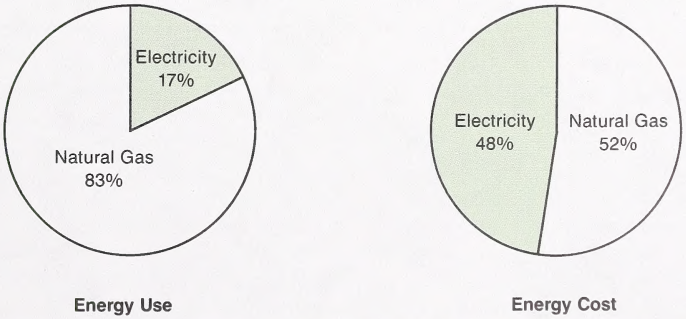
An energy audit determines initially how energy is being used and how much it costs in each area. Energy conservation measures are then identified which can result in energy cost savings. On average, the Energy Bus has identified a potential reduction in energy costs of about 20 per cent.

The food and beverage processing industry includes subsectors such as meat, poultry, dairy products, soft drinks and liquor processing and preparation. This is an energy-intensive sector because considerable amounts of electricity and natural gas are required to process these products.

Energy audits of 19 food and beverage processing facilities by staff of Alberta's Energy Bus audit program have shown there is good potential for energy cost savings in this sector. The total energy use and cost at these 19 facilities is about $17 million annually.

Figure 1 shows the breakdown of energy use and cost for electricity and natural gas in the food and

FIGURE 1
Energy Use and Cost in Food and Beverage Processing Industry



beverage sector. Electrical use is the lowest, only 17 per cent compared with 83 per cent for natural gas. However, electricity is a major cost area, accounting for 48 per cent of the total energy cost in this sector. There is a difference in the percentage of energy used and its associated cost because the average price of a unit of electricity is four to five times more than the equivalent unit of natural gas.

Figure 2 indicates the areas of energy use for food and beverage processing facilities. Most of the energy (electricity and natural gas) is used in the process portion of the overall operation.

The potential for electrical savings through power factor correction was identified in 15 of the 19 audited facilities. For these facilities, the payback period for investing in power factor correction equipment would be less than two years. Power factor correction will not reduce electrical energy consumed but will reduce electrical costs. This occurs because power factor correction reduces the demand reading on the meter, thereby reducing the charges associated with demand.

In the 19 processing facilities, the total potential for savings was identified at just over $1 million per year – 26 per cent of these savings being associated with electrical use. As shown in Figure 3, power factor correction is a major component of the potential savings, representing 42 per cent of the total electrical savings identified.

FIGURE 2
Energy Use in Food and Beverage Processing Industry

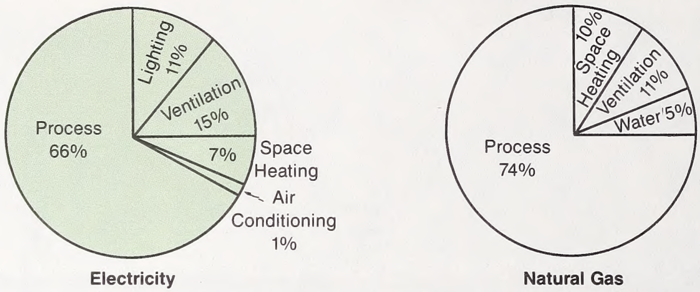
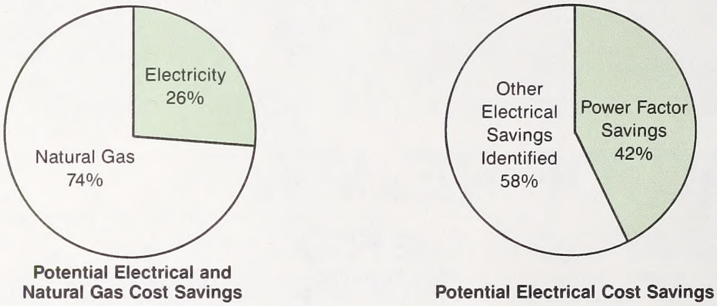
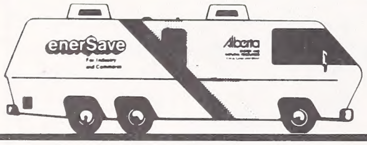


FIGURE 3
Potential for Savings in Food and Beverage Processing Industry



FOR MORE INFORMATION

The article Saving Money Through Power Factor Improvement was researched by Les Sladen who also completed the Sector Review. For detailed information on energy cost saving calculations and the energy audit database, contact the industrial section of the Energy Efficiency Branch: Phone 427-5200 (collect).



ENERGY $AVER$

Energy $aver$ is a series of fact sheets about energy conservation measures that have wide application in Alberta. Each issue highlights a different technology and its successful use in the province. The Sector Review summarizes energy use patterns of different facilities that have used the Alberta Energy Bus audit service. Comments, questions and suggestions are welcome.

Write or phone (collect) to be placed on the mailing list. You may also obtain Energy $aver$ back issues or arrange for an Energy Bus audit (conducted at no charge).

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